

Intermodulation Components in the Transmitter RF Output Due to High Voltage Power Supply Ripple

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A study was conducted to determine if it would be economically feasible to eliminate the 400-Hz motor-generator sets used to provide power to the high-voltage power supplies of the 20-kW transmitters and replace them with a 60-Hz high-voltage power supply. The efficiency of a power supply that runs from the 60-Hz line directly would pay for itself in about seven years and could be designed so that the transmitter would meet all the incidental phase and amplitude modulation specifications.

I. Introduction

A study was conducted to determine if it would be economically feasible to eliminate the 400-Hz motor-generator (MG) sets used to provide power to the high-voltage power supplies of the 20-kW transmitters and replace them with a 60-Hz high-voltage power supply. After the data were analyzed and it was determined that the payoff point would be seven years, the question came up as to what the intermodulation components would be due to the ripple voltage of the new 60-Hz power supply. This article covers the question of modulation in the radiated output of the transmitter that may be introduced if the 400-Hz motor-generator was replaced with a single 60-Hz power supply excited from the main power line.

II. Conclusion

It was determined by cost analysis that it takes seven years to break even when the single 60-Hz power supplies replace the present 400-Hz MG set and high-voltage power supply. It may be noted in the data below that the low-frequency components have the larger ripple voltages. This is caused by

the rotating machinery which would be automatically eliminated by the new 60-Hz power supplies.

III. Power Supply Design

The amplitude of ripple on the high-voltage power supply is what determines the amount of amplitude and phase modulation on the transmitters RF output; the ripple frequencies also determine the demand placed on the high-voltage power supply filter system. This ripple voltage is impressed directly on the klystron which in turn causes the beam voltage to rise and fall at the ripple amplitude, resulting in amplitude modulation. Also, the higher and lower voltage causes the electron beam to change in velocity, thus causing phase modulation (PM). The power supply can be designed using a three-phase full-wave bridge; this produces a 360-Hz ripple frequency. However, a better arrangement would be to wind the transformer so that it looks like a six-phase circuit; this would double the ripple frequency (720 Hz). The new power supply filter would be designed to have a cutoff frequency of approximately 20 Hz that is low enough to attenuate any 60-Hz frequencies and reduce any strong modulations to negligible amounts.

IV. DSN Survey

The DSN was surveyed to determine what the ripple voltages were throughout the DSN in order to check the modulation components in the transmitted RF. The specification for AM and PM modulation for the 20-kW transmitter calls for incidental phase modulation to be less than 1 degree rms and incidental amplitude modulation to be 60 dB below the main carrier. The ripple frequency and amplitude as reported from the DSN stations are listed below.

DSS	Ripple frequency, Hz	Peak-to-peak ripple amplitude
44	20	18
44	2400	4
62	20	20
62	2400	Negligible
63 & 61	2400	Negligible
42	20	16
42	2400	Negligible
43	20	5
43	2400	Negligible

V. Calculations

The calculations for determining incidental amplitude and phase modulation are shown below.

A. Amplitude Modulation Calculations

The total AM power in the sideband is expressed by the formula

$$P_0 = 20 \log_{10} \frac{0.8V_0}{V_r}$$

where

$$V_0 = \text{beam voltage}$$

$$V_r = \text{beam ripple voltage in rms}$$

Out specification calls for 60 dB or more below the carrier; this would calculate out to $16V_r$ or less.

B. Phase Modulation Calculation

The formula for calculating phase modulation (that is, the phase change with respect to the average phase) is

$$\frac{\Delta\theta}{\theta} = \frac{1}{2} \frac{\Delta V_0}{V_0}$$

or

$$\frac{\Delta\theta}{\theta} = \frac{\Delta V_0}{2V_0}$$

where

$$\theta = \text{electrical length of tube}$$

At 18 kV (which is approximately 20 kW), the phase length is 45.81 radians for the 20-kW tube or 2620.0 degrees. This would calculate out to be 0.07291 deg/volt. The specification is a maximum of 1.0 degree rms phase modulation. In terms of power supply ripple voltage, this would be 13.8 volts rms (39 V p-p) or less in order to meet the specification.

VI. Summary

As can be seen, the present specification is adequate to cover the new power supply, and there should be no problem in meeting the specification and reducing the energy consumption.

It may also be noted that the incidental modulations caused by power supply ripple can be predicted mathematically if the ripple components are known.